

Numerical Modeling of Acoustic Propagation in a Variable Shallow Water Waveguide

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LONG-TERM GOAL

The long term scientific goal is to better understand the effects of shallow water variability on acoustic propagation at moderate frequencies. Potential sources of water column variability include random background internal waves as well as quasi-deterministic, event-like soliton packets.

OBJECTIVES

The objectives of the present work are to develop models and improve simulation tools useful in achieving the long-term scientific goal.

APPROACH

Experimental observations are used to guide the development of theoretical models. The models are implemented numerically and compared to experimental results.

WORK COMPLETED

My previous work concentrated on numerical modeling. These models were used in two journal articles that were published in FY98.

I spent the summer of 1997 as an American Society for Engineering Education-U.S. Navy Senior Faculty Fellow visiting NRL-DC. I was involved in modeling and data analysis of the 1995 Shallow Water Acoustics Random Medium (SWARM 95) experiment [PI: M. Orr, NRL; Apel et al., 1997]. Using CTD casts and bathymetric measurements taken during SWARM, acoustic propagation was simulated. A modal analysis was initiated of SWARM data taken along the 32 element NRL array located 42 km downrange. Both the 224 Hz and 400 Hz data were considered for the same time windows. Three separate versions of mode filtering were implemented: a quadrature scheme that approximates the modal orthogonality condition, a least-squares solution, and a filter that infers the mode one structure directly from early arriving part of the acoustic field. For the time windows considered, the results from the three methods were consistent. Modal decorrelation times of a few minutes were observed. This is generally consistent with what was observed along the Woods Hole array located closer to the sources [Headrick, 1997].

In FY98, I sought to develop a model to explain the observed rapid decorrelation of the acoustic modes that was observed in SWARM.

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RESULTS

A model was developed for acoustic propagation through solitary waves. The solitary waves were treated as mode coupling packets moving through the acoustic propagation regime without changing shape. The model quantifies how decorrelation is a consequence of the interference pattern between the modes changing as the packet moves. In the special case of weak mode coupling, decorrelation occurs when the solitary waves travel an appreciable fraction of the equivalent ray cycle length. When the mode coupling is strong, the interaction between all excited mode pairs must be considered and more rapid decorrelation can be expected.

The model was implemented numerically using a mixed normal mode/parabolic equation approach [Preisig and Duda, 1997]. Even for the case of a single symmetric soliton, decorrelation time scales on the order of a few minutes were predicted. An interesting feature of the simulations is that they predicted a partial recorrelation of the modes at time scales of a few tens of minutes.

In collaboration with Altan Turgut of NRL, more detailed simulations were performed mimicking the situation at SWARM. Turgut also decomposed a more extended segment of NRL array data into normal modes. A partial recorrelation of the first mode was observed consistent with the modeling. These results were presented at an Acoustical Society Meeting [Rouseff and Turgut, 1998].

IMPACT/APPLICATIONS

Variability in the water column affects the temporal and spatial correlation scales of the acoustic field. A capability to model and predict the correlation scales is essential for data analysis and for planning future experiments.

RELATED PROJECTS

Investigators at several institutions are involved in SWARM analysis: NRL, WHOI, the Naval Postgraduate School, and the University of Delaware.

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